Figure 31 is a cross-sectional view schematically illustrating a portion of an implantable stimulation apparatus having an external power source and pulse generator in accordance with an embodiment of the invention.

Figure 32 is a cross-sectional view schematically illustrating a portion of an implantable stimulation apparatus having an external power source and pulse generator in accordance with another embodiment of the invention.

Figure 33 is a cross-sectional view illustrating in greater detail a portion of the implantable stimulation apparatus of Figure 32.

Figure 34 is a cross-sectional view schematically illustrating a portion of an implantable stimulation apparatus and an external controller in accordance with another embodiment of the invention.

Figure 35 is a cross-sectional view schematically illustrating a portion of an implantable stimulation apparatus and an external controller in accordance with yet another embodiment of the invention.

Figure 36 is a cross-sectional view schematically illustrating a portion of an implantable stimulation apparatus in accordance with yet another embodiment of the invention.

Figure 37 is an isometric view and Figure 38 is a cross-sectional view illustrating an implantable stimulation apparatus in accordance with an embodiment of the invention.

Figure 39 is a cross-sectional view illustrating an implantable stimulation apparatus in accordance with yet another embodiment of the invention.

Figure 40 is a schematic illustration of an implantable stimulation apparatus in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

The following disclosure describes several methods and apparatus for intracranial electrical stimulation to treat or otherwise effectuate a change in neural-functions of a patient. Several embodiments of methods in accordance with the invention are directed toward enhancing or otherwise inducing neuroplasticity to

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effectuate a particular neural-function. Neuroplasticity refers to the ability of the brain to change or adapt over time. It was once thought adult brains became relatively "hard wired" such that functionally significant neural networks could not change significantly over time or in response to injury. It has become increasingly more apparent that these neural networks can change and adapt over time so that meaningful function can be regained in response to brain injury. An aspect of several embodiments of methods in accordance with the invention is to provide the appropriate triggers for adaptive neuroplasticity. These appropriate triggers appear to cause or enable increased synchrony of functionally significant populations of neurons in a network.

Electrically enhanced or induced neural stimulation in accordance with several embodiments of the invention excites a portion of a neural network involved in a functionally significant task such that a selected population of neurons can become more strongly associated with that network. Because such a network will subserve a functionally meaningful task, such as motor relearning, the changes are more likely to be lasting because they are continually being reinforced by natural use mechanisms. The nature of stimulation in accordance with several embodiments of the invention ensures that the stimulated population of neurons links to other neurons in the functional network. It is expected that this occurs because action potentials are not actually caused by the stimulation, but rather are caused by interactions with other neurons in the network. Several aspects of the electrical stimulation in accordance with selected embodiments of the invention simply allows this to happen with an increased probability when the network is activated by favorable activities, such as rehabilitation or limb use.

The methods in accordance with the invention can be used to treat brain damage (*e.g.*, stroke, trauma, etc.), brain disease (*e.g.*, Alzheimer's, Pick's, Parkinson's, etc.), and/or brain disorders (*e.g.*, epilepsy, depression, etc.). The methods in accordance with the invention can also be used to enhance functions of normal, healthy brains (*e.g.*, learning, memory, etc.), or to control sensory functions (*e.g.*, pain).

Certain embodiments of methods in accordance with the invention electrically stimulate the brain at a stimulation site where neuroplasticity is occurring. The stimulation site may be different than the region in the brain where neural activity is typically present to perform the particular function according to the functional organization of the brain. In one embodiment in which neuroplasticity related to the neural-function occurs in the brain, the method can include identifying the location where such neuroplasticity is present. This particular procedure may accordingly enhance a change in the neural activity to assist the brain in performing the particular neural function. In an alternative embodiment in which neuroplasticity is not occurring in the brain, an aspect is to induce neuroplasticity at a stimulation site where it is expected to occur. This particular procedure may thus induce a change in the neural activity to instigate performance of the neural function.. Several embodiments of these methods are expected to produce a lasting effect on the intended neural activity at the stimulation site.

The specific details of certain embodiments of the invention are set forth in the following description and in Figures 1A-40 to provide a thorough understanding of these embodiments to a person of ordinary skill in the art. More specifically, several embodiments of methods in accordance with the invention are initially described with reference to Figures 1-5C, and then several embodiments of devices for stimulating the cortical and/or deep-brain regions of the brain are described with reference to Figures 6-40. A person skilled in the art will understand that the present invention may have additional embodiments, or that the invention can be practiced without several of the details described below.

A. Methods for Electrically Stimulating Regions of the Brain

1. Embodiments of Electrically Enhancing Neural Activity

Figure 1A is a schematic representation of several neurons N1-N3 and Figure 1B is a graph illustrating an "action potential" related to neural activity in a normal neuron. Neural activity is governed by electrical impulses generated in